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(PROFESSIONAL PAPER.)

THE SO-CALLED TOBACCO WIREWORM IN VIRGINIA.[1]

By G. A. Runner,
Entomological Assistant, Southern Field Crop Insect Investigations.

INTRODUCTION.

For the study of insects injurious to tobacco the Bureau of Entomology during the last four summers has maintained a temporary field station at Appomattox, Va. Work of this station has been under the direction of Mr. W. D. Hunter, in Charge of Southern Field Crop Insect Investigations, and more immediately under the supervision of Mr. A. C. Morgan. Laboratory quarters were furnished by the Tenth Congressional District Agricultural School. The results of investigations of the tobacco Crambus (*Crambus caliginosellus* Clem.) are given in this bulletin.

The work in Virginia was in cooperation with the State experiment station and the Bureau of Plant Industry of the U. S. Department of Agriculture. Through an agreement with the cooperators, the Bureau of Entomology was furnished all data pertaining to the rotation of crops grown in connection with tobacco, and the plats of the several tobacco stations in the State were placed at the disposal of the agent in charge, for inspection and experiment. The records of these stations, extending over a series of years, are of great value in determining the crop rotations and cultural methods of control best adapted to the special conditions to be dealt with in different tobacco sections.

The experimental work with tobacco in Appomattox County, Va., was begun by the Bureau of Soils in 1904. The work has since been conducted cooperatively by the Bureau of Plant Industry and the Virginia experiment station. Since the first, owing to the work of

[1] Throughout the tobacco-growing sections of Maryland, North Carolina, and Virginia the larvæ of the tobacco Crambus are generally known as "wireworms." They are also known in other sections as "tobacco wireworms," "budworms," "corn worms," "stalk worms," "heart worms," "cutworms," "stem worms," "root webworms," and "screw worms." In parts of Tennessee and Kentucky the larvæ are commonly called "screw worms." The term "wireworm" is also applied, as in other sections, to the true wireworms (larvæ of Elateridæ), which the Crambus larvæ in no way resemble.

Note.—This bulletin is descriptive of an insect enemy of tobacco and corn. Of especial interest in the eastern tobacco and corn districts.

the tobacco Crambus, great difficulty has been encountered, in many of the experiments, in getting the perfect stand of plants so essential for comparative tests. This led to a study of the life history of the insect and of the somewhat extensive cultural experiments by the Bureau of Entomology aimed at its control. The effect of certain crop rotations in reducing injury from the tobacco Crambus was noticed during the early progress of the cultural investigations by Mr. E. H. Mathewson, Crop Technologist of the Bureau of Plant Industry, to whom the writer is indebted for suggestions concerning the cultural methods of control undertaken by the Bureau of Entomology.

GENERAL HABITS AND ECONOMIC IMPORTANCE OF THE GROUP TO WHICH THE TOBACCO CRAMBUS BELONGS.

The larvæ of insects included in the family Crambidæ, to which the tobacco Crambus belongs, feed mainly on the grasses (Gramineæ), although some of them subsist on plants of other families. Many construct tubular, web-lined galleries near the roots of the plants on which they feed, and some bore or tunnel into the roots or stems; for this reason they have been named "root webworms." The moths, or adults, are medium or rather small in size, with brown, yellow, or white colors prevailing. Many species have metallic markings on the forewings, which are comparatively long and usually narrow. When at rest the forewings are rolled around the body and conceal the hind wings, which are folded beneath. This gives the body the appearance of a tiny cylinder, and accounts for the term "close-wings." The species are widely distributed over the globe, but are apparently most numerous in temperate climates. In North America comparatively few are known, and the majority of these belong to the genus Crambus, in which Dr. H. G. Dyar[1] catalogues 60 species.

Moths of the genus Crambus fly mostly on dark afternoons and during the early part of the night. They are more common in open fields. When disturbed they make short erratic flights, rarely flying more than a few rods at a time. They usually alight head downward on the stems of plants, and their color often harmonizes so perfectly with their surroundings that they can with difficulty be seen. Most of the species are single-brooded; but as the moths of different species emerge successively throughout the season, one or more of the latter are present in most localities from spring until late fall. Though various species of Crambus are common in most localities, they seldom attract much attention unless some important crop is attacked. This is due (1) to the fact that the moths are small and inconspicuous, (2) to the underground feeding habits of the arvæ, land (3) to the fact that damage from different species is distributed throughout the growing season.

[1] Dyar, Harrison G. A List of North American Lepidoptera * * *. U. S. Nat. Mus. Bul. 52, pp. 404-410, 1902.

The principal species of the genus of economic importance in this country are: *Crambus caliginosellus* Clemens, which attacks tobacco and corn; *C. vulgivagellus* Clemens, an enemy of corn, wheat, rye, and grasses; *C. trisectus* Walker, an enemy of grasses, oats, and corn; *C. laqueatellus* Clemens, which attacks corn and oats; *C. zeellus* Fernald, *C. luteolellus* Clemens, and *C. mutabilis* Clemens, enemies of corn; and *C. hortuellus* Hübner, which is injurious to the cranberry. The wide distribution of several of these and their great capacity for injury give them rank as species of considerable economic importance. Damage by them to cultivated crops is, in most cases, the result of unusual conditions. Their range of food plants is not large, and the larvæ are inclined to remain in or near one place. The moths frequent the weedy fields, pastures, or meadows which contain the natural food plants of the larvæ, and the greater number of eggs are deposited in such localities. When such land is plowed up the larvæ are forced to live on other than their natural food plants. With crops such as corn and tobacco this means a concentration of larvæ from many of the wild or natural food plants to the comparatively few cultivated plants.

ECONOMIC IMPORTANCE OF THE TOBACCO CRAMBUS.

The tobacco Crambus (*Crambus caliginosellus* Clem.) occurs in most, if not all, of the tobacco-growing districts of the Eastern States, but it seems to be most destructive in certain sections of Maryland and Virginia. It is especially destructive in the famous "dark-tobacco district" of the Piedmont section of middle Virginia, although found in all sections of the State in which tobacco is grown. In Virginia the damage to the tobacco crop alone from the insect is estimated to average at least $800,000 annually.

At the Virginia tobacco experiment stations, at Appomattox, Bowling Green, and Chatham, injury has been recorded for a number of years. The reduction in value of the crop has been great, amounting to about 14 per cent annually, through failure to secure an early stand of plants. At the Appomattox Station, in one of the experimental fields, there was a loss in 1910 amounting to about 27 per cent. In 1911 there was still greater loss in some of the plats. In many fields in the county fully one-half of the plants were attacked, making several replantings necessary. At the Chatham Station in 1909 there was an estimated decrease in the value of the crop amounting to about $15 per acre.

In 1912 considerable damage occurred to tobacco in Montgomery County, Tenn., and in Christian and Todd Counties, on the southern border of Kentucky, growers in a number of instances reporting fully 40 per cent of the plants destroyed.

The insect has for many years been a serious pest to tobacco and corn in Maryland. W. G. Johnson, formerly State entomologist, recorded the species as extremely abundant and destructive in Prince Georges, Cecil, Kent, Queen Anne, and Dorchester Counties in 1897, and reported damage in various parts of the State in 1898, 1899, and 1900, many fields of young corn being almost completely destroyed.

M. H. Beckwith mentions it as injurious to corn in Delaware, and John B. Smith has recorded injury to corn in New Jersey.

ORIGIN AND DISTRIBUTION.

Crambus caliginosellus has been recorded only from North America. Its preference for the naturalized buckhorn plantain and oxeye daisy as food plants, however, points to the possibility that it has been introduced from Europe.

In literature the recorded distribution of the species is as follows: Ontario (Saunders, Felt, and Fernald); New York (Grote, Felt, and Fernald); Delaware (Beckwith); New Jersey (Smith); Maryland (Johnson and Howard); Massachusetts, Pennsylvania, District of Columbia, North Carolina, Illinois, and Texas (Fernald); Virginia (Mathewson, Anderson, and Runner); Ohio (Gossard).

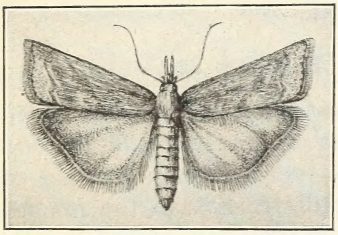

FIG. 1.—Adult, or moth, stage of the tobacco Crambus, or "wireworm" (*Crambus caliginosellus*). Enlarged. (Original.)

In collections in the National Museum are specimens from the following localities: Washington, D. C. (August Busck); Plummers Island, Md. (H. S. Barber); Plainfield, N. J. (F. O. Herring); Pittsburgh, Pa. (H. Engel); Clarksville, Tenn. (A. C. Morgan); Chapel Hill, Tenn. (G. G. Ainslie); Vienna, Va. (R. A. Cushman).

Records of the Bureau of Entomology show the insect to be present in Pennsylvania, Delaware, Maryland, Virginia, West Virginia, North Carolina, South Carolina, Ohio, Tennessee, and Kentucky.

These records indicate a wide distribution, but as most reports of injury to cultivated crops come from certain portions of the Eastern States it is probable that severe injury occurs only in localities where natural food plants are exceedingly abundant, and where crops subject to injury are planted at the time the larvæ are completing their growth and are in their most active feeding stage.

SEASONAL HISTORY.

The moths (fig. 1) emerge during summer, the heaviest emergence occurring at Appomattox, in central Virginia, during the first and second weeks in August. The earliest emergence takes place during

the latter part of June, but moths are not abundant until about the third week in July. From this time their numbers gradually increase until about the second week in August, when they are exceedingly numerous, at times appearing almost in swarms in weedy fields when disturbed. From the middle of August there is a rapid decrease and after the 1st of September only an occasional one can be found. Table I gives dates of emergence of moths from some of the field cages at Appomattox in 1910.

TABLE I.—*Emergence of moths of the tobacco Crambus in outdoor rearing cages at Appomattox, Va., 1910.*

Larvæ collected—	Food plant on which found.	Moth emerged—	Larvæ collected—	Food plant on which found.	Moth emerged—
1910.		1910.	1910.		1910.
June 4	Tobacco	July 2.	June 26	Tobacco	July 18.
Do	do	July 21.	Do	Wild carrot	Aug. 13.
Do	do	July 22.	Do	Tobacco	Aug. 6.
Do	do	Aug. 3.	Do	do	Aug. 15.
June 5	do	July 3.	June 28	Plantain	July 14.
Do	Corn	July 14.	Do	Daisy	Aug. 15.
Do	Senecio	July 22.	Do	Aster (stickweed)	Aug. 7.
Do	Plantain	July 23.	July 1	Plantain	July 29.
June 6	Corn	July 26.	Do	Tobacco	Aug. 14.
Do	Daisy	Aug. 1.	Do	Corn	July 27.
Do	Aster spp	July 29.			

The females die soon after egg laying is finished. There is apparently only one generation a year, the eggs hatching in summer and the larvæ completing their growth during the following year. The greater number of larvæ are in the pupal stage during the first half of July.

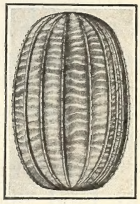

FIG. 2.—The tobacco Crambus: Egg. Greatly enlarged. (Original.)

DESCRIPTION.

THE EGG.

The egg (fig. 2) is creamy white when first deposited, but gradually assumes a pinkish shade, which deepens to orange rufous before hatching. The average length is 4 mm. and the diameter 0.32 mm. It is regularly oval, with the ends slightly truncate, and has a polished appearance. There are about 18 longitudinal carinæ and numerous transverse striæ.

THE LARVA.

FIRST INSTAR.

When first hatched, the body of the larva is semitransparent, and the alimentary canal can be plainly seen. The outline of the body, when seen from above, is almost triangular. The larva is white, or pale yellowish white, and about 1 mm. long, with a few scattered, light-colored hairs on the head and body. The head shield measures 0.15 mm. in width, is yellowish brown, and moderately bilobed, with the clypeus attaining the apical third. The cervical shield is tinged slightly with brownish. Five pairs of prolegs occur on the 7th to 10th segments, inclusive, and on the 13th segment.

LAST INSTAR.

The full-grown larva (figs. 3, 4) is about 15 mm. long, and yellowish white, with a tinge of pink dorsally. The hairs of the body are slender, brownish, and set on large fuscous tubercles. The head shield measures 1.2 mm. in width, and is pale yellowish

brown, flecked with darker brown. The cervical shield is distinct, shining, yellowish brown, tinged with fuscous, and bears 12 hairs in two transverse equal rows. The anal shield is pale fuscous. About the middle of abdominal segments 3, 4, 5, and 6, and slightly above the spiracles, is a series of distinct, dark fuscous, chitinous areas about the size and shape of spiracles, one to each segment.

The arrangement of the tubercles is as follows: Beneath the anterior margin of the cervical shield is a tubercle bearing two hairs. The mesothorax above bears eight setigerous tubercles on the anterior margin, each, except the lateral tubercle, with two hairs. Posteriorly it is provided with three bare tubercles, of which the median is narrow and transverse. The metathorax is armed, as is the mesothorax. Each abdominal segment above the spiracles bears two transverse rows of four tubercles each. The anterior dorsal pair are subquadrate, with the posterior lateral angles strongly rounded. The posterior dorsal pair are oblong, transverse, about half as long as the anterior, with the posterior lateral angles strongly rounded. The anterior lateral tubercles are supraspiracular, irregularly quadrate, with the lower margin produced diagonally behind the spiracle, emarginate at the spiracle and before the impressed area on segments 3, 4, 5, and 6. The corresponding tubercle on segment 8 has the produced portion isolated and is placed anterior to the spiracle. The posterior lateral tubercles are transverse, elongate, and somewhat oblique.

FIG. 3.—The tobacco Crambus: Full-grown larva, or "wireworm." Much enlarged. (Original.)

Abdominal segments 1 to 7 each bear a minute spinule anterior to and nearly equidistant from the spiracle and the supraspiracular hair.

The legs are pale brown, the maxillary palpi brown, and the mandibles brownish fuscous at apices.

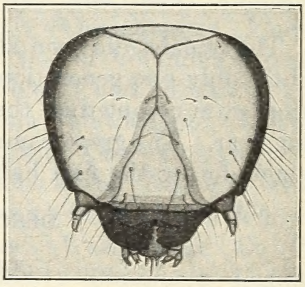

FIG. 4.—The tobacco Crambus: Head of larva. Greatly enlarged. (Original.)

The color of larvæ collected from different food plants varies considerably, this being merely an effect of the color, whether light or dark, of the food in the alimentary canal. Larvæ collected from corn are considerably lighter than those collected from tobacco.

THE PUPA.

The pupa (fig. 5) measures about 8 mm. in length and 2 mm. in greatest width. The general color is dark brown, or pale yellowish brown when newly transformed, with the appendages and segments marked with dark brown. The head is blunt, with a median apical emargination. The tips of the wings are rounding on abdominal segment 5; the margin of the inner wing is visible over segments 2, 3, and 4. The spiracles are not prominent, the first three pairs being set on blunt tubercles. The cremaster is transversely rounded oblong, with a lateral bristle near the apex.

THE ADULT, OR MOTH.

Expanse of wing, 13–25 mm. Head, palpi, and thorax dark fuscous, sprinkled with gray scales. Fore wing dark fuscous, sprinkled with brown or yellowish, and frequently with a few gray scales; median line dark brown, often edged with white, aris-

ing a little beyond the middle of the costa, extending outward, forming a very acute angle, thence backward across the end of the cell to the hind margin, a little beyond the middle, and giving off an outward angle on the fold. Subterminal line dark brown, edged outwardly with dark lead-colored scales, and frequently dentate along the first part of its course. It arises from the costa about half way between the median line and the apex, extending down to a point beyond the end of the cell, where it forms an outward angle, thence to the hind margin, a little within the anal angle, giving off an inward angle on the fold. This angle is frequently connected along the fold with the outward angle of the median line; terminal line dark brown, rather indistinct. The lines are often obliterated more or less, especially the median. Fringes dark leaden gray. Hind wings dark fuscous; fringes a little lighter. [Fernald, 1896.] (See fig. 1.)

The moths vary somewhat in color and distinctness of markings, some specimens being much darker than others when first transformed. In the hind wing the frenulum is a single short spine in the male. In the female the frenulum is more slender and is very finely divided at the tip. In the female of a number of other species of this genus the frenulum consists of two distinct spines.

FIG. 5.—The tobacco Crambus: Pupa. Much enlarged. (Original.)

LIFE HISTORY.

HABITS OF THE MOTHS.

The moths fly during late afternoon, on dark days, and during the early part of the night. They are attracted to light, but in comparatively small numbers considering their great abundance at certain times. The majority of the females collected at trap lights are those which have deposited their eggs. During the day, when disturbed, they make short, erratic flights, usually alighting head downward on the stems of weeds and grasses, their tightly closed wings and grayish color making them very inconspicuous. As with other members of the genus Crambus, their long palpi, extending parallel to the stem of the plant on which they are at rest, help to make the outlines of the body conform to the appearance of that part of the plant.

OVIPOSITION.

When the moths were confined in cages, the eggs were deposited at random over the surface of the ground. They seemed dry when deposited, rolled about easily, and did not adhere to papers placed over the soil in the rearing cages, or to glass when females were confined in large test tubes. Normally the eggs are doubtless placed in the same manner, for on two occasions eggs were found on the upper surface of leaves of sweetbrier lying flat on the ground. Egg laying commences shortly after the moths emerge. Fertile eggs were not obtained from moths reared in the cages.

Records obtained from a large number of females, collected in the fields and placed in separate cages for egg deposition, show the average number of eggs laid to be 177. Among the records obtained at Appomattox, Va., during 1910, are those in Table II.

TABLE II.—*Number of eggs laid by the tobacco Crambus, Appomattox, Va., 1910.*

No. of female.	Moth collected.	Period of oviposition.	Number eggs laid.	No. of female.	Moth collected.	Period of oviposition.	Number eggs laid.
	1910.	1910.			1910.	1910.	
1	July 8	July 9–13	218	10	Aug. 11	Aug. 12–15	83
2	do	do	68	11	do	Aug. 12–16	203
3	do	July 9–14	271	12	Aug. 14	Aug. 15–20	218
4	July 10	July 11–14	156	13	do	Aug. 15–18	194
5	July 12	July 13–18	211	14	Aug. 15	Aug. 16–20	222
6	July 17	July 18–22	316	15	do	Aug. 16–19	91
7	do	July 18–23	287	16	do	Aug. 16–21	238
8	July 25	July 26–30	77	17	do	Aug. 16–18	63
9	Aug. 11	Aug. 12–16	301				

Several individual females laid over 300 eggs, and over 300 were obtained in several instances by dissection. It is probable that the average number of eggs deposited normally is above rather than below the average obtained in the cages, as some of the moths may have laid eggs before capture, although records were not included from moths which deposited eggs within 12 hours after capture.[1]

The period of oviposition lasts from 3 to 5 days, the females dying shortly after egg laying is finished. The records of two females collected in the field on August 10, 1910, are given in Table III.

TABLE III.—*Rate of oviposition of the tobacco Crambus, Appomattox, Va., 1910.*

Female No. 1.		Female No. 2.	
Date.	Number of eggs deposited.	Date.	Number of eggs deposited.
1910.		1910.	
Aug. 11	7	Aug. 10	93
Aug. 12	89	Aug. 11	87
Aug. 13	70	Aug. 12	23
Aug. 14	36	Aug. 13	5
Aug. 15	19		
Total	221	Total	208

DURATION OF THE EGG STAGE.

The period of incubation was found to be from 5 to 9 days, the greater number of eggs hatching about the sixth day at ordinary summer temperatures.

[1] The dissection of 17 females of *Crambus caliginosellus* collected in the field during the third week in July, 1912, showed that 8 of the 17 collected contained more than 100 eggs. The number of eggs (mature or nearly mature) found in the 8 moths containing more than 100 eggs was as follows: 143, 322, 127, 290, 307, 124, 342, 208.

FIG. 1.—INJURY OF THE TOBACCO CRAMBUS, OR "WIREWORM," TO TOBACCO.

FIG. 2.—INJURY OF THE TOBACCO CRAMBUS, OR "WIREWORM," TO CORN.

WORK OF THE TOBACCO CRAMBUS.

FIG. 1.—POOR STAND OF TOBACCO RESULTING FROM PLANTING ON WEEDY LAND.
Note heavy growth of oxeye daisy in part of field not in tobacco.

FIG. 2.—WILD CARROT AND OTHER WEEDS IN FIELD OF RED CLOVER.
Injury from the "wireworm" occurs when land of this kind is planted in tobacco or corn.

RELATION OF WEEDY LAND TO INJURY BY TOBACCO CRAMBUS.

TABLE IV.—*Duration of egg stage of the tobacco Crambus, Appomattox, Va., 1910.*

Lot No.	Eggs laid—	Eggs hatching—	Incubation period.	Lot No.	Eggs laid—	Eggs hatching—	Incubation period.
	1910.	1910.	*Days.*		1910.	1910.	*Days.*
1	July 7	July 12	5	8	Aug. 12	Aug. 17–18	5–6
2	July 11	July 19–20	8–9	9	Aug. 13	....do	4–5
3	July 12	July 19	7	10	Aug. 14	Aug. 19–20	5–6
4	July 13	July 19–20	6–7	11	Aug. 15	Aug. 20	5
5	July 25	July 31	6	12	Aug. 16	Aug. 21–22	5–6
6	July 26	Aug. 1–2	6–7	13	Aug. 17	Aug. 23–24	6–7
7	Aug. 11	Aug. 16–17	5–6				

HABITS OF THE LARVÆ.

NATURAL FOOD PLANTS.

Larvæ of the tobacco Crambus have been found feeding on the following wild plants:

Buckhorn plantain (*Plantago lanceolata*).
Oxeye daisy (*Chrysanthemum leucanthemum*).
Wild aster or "stickweed" (*Aster ericoides* and other species).
Wild carrot (*Daucus carota*).
Sheep sorrel (*Rumex acetosella*).
Senecio (*Senecio jacobæa*).
White-top (*Erigeron annuus* and other species).

The first two plants named, the buckhorn plantain and the oxeye daisy (Pl. II, fig. *a*), were found to be the main food plants of the larvæ in the localities studied. The eradication or control of these weed pests, therefore, will result in comparative immunity from loss by this insect. Both species of plants have been found heavily infested in many localities in widely separated sections. During early spring the plantain seems to be the preferred food plant; later a heavy infestation occurs on both plantain and daisy.

On July 8, 1910, 23 out of 25 oxeye daisy plants examined in a weedy field were infested, there being a total of 69 larvæ about the roots. As many as 20 larvæ have been collected from one plant of the oxeye daisy.

In tobacco-growing sections of Tennessee and Kentucky white-top is a frequent food plant.

When meadows are plowed up and planted to tobacco there is frequently serious injury from the "wireworms." (See Pl. II.) Where such injury has occurred the weeds mentioned above have invariably been found abundant in the sod, which explains the presence of the "worms." Injury has not been observed where there had been previously a clean growth of grass or clover. Attempts to rear adults from larvæ confined in field cages containing only timothy and clover resulted in failure, although the larvæ lived for a considerable time without other food.

INJURY TO TOBACCO.

The tobacco is attacked soon after planting, and feeding by the larvæ continues until the first or second week of July. The larvæ usually commence operations just below the surface of the ground, although newly set plants are frequently attacked at the "bud" or whorl of terminal leaves. As feeding continues the larvæ, especially the smaller ones, frequently enter the stalk and tunnel upward, the burrows often extending to the base of the first leaves and some distance above the surface of the ground. (See Pl. I, fig. *a*.) When not feeding the "worms" are found about the base of the plant, usually in cylindrical, web-lined galleries, which extend from the plant, often for several inches, beneath the surface of the soil.

Injured plants may usually be detected by their stunted or wilted appearance, which is more noticeable during hot, dry weather. The stems are in some cases entirely cut off, although this form of injury is rather unusual.

Although plants often partially recover they do not obtain full growth, and it is evident that the presence of many dwarfed or stunted plants must result in very materially lessening the yield. The value of the crop is greatly decreased also, owing to the large proportion of late plants resulting from replanting. Early planted tobacco is usually better in quality than the late planted, it being finer and more elastic, curing better, and consequently bringing higher prices. The attacks of the larvæ often make it necessary to reset the crop several times, and a good stand of plants is not secured, if at all, until too late to make the crop as profitable as it should be.

INJURY TO CORN.

Owing to its wide distribution in the Eastern States the tobacco Crambus is a serious pest to the corn crop. Injury has been noted in many localities where little tobacco is grown, and it is probable that damage to corn amounts to even more than that to tobacco. As with tobacco, injury is most severe when corn is planted on land which has been in weedy pasture or meadow previously, or when planted on land which has not been under cultivation for a number of years and on which there has been a rank growth of weeds. On such land it is usually difficult to secure a satisfactory stand of corn, and the yield is greatly reduced. (See Pl. I, fig. *b*.) In central Virginia many fields under observation were replanted several times, and owing to the lateness of the season when a stand was secured the value of the crop was decreased fully one-third. Corn or tobacco planted on newly-cleared land seldom suffers injury from the Crambus. Since the species of weeds which are the natural food plants of the insect do not thrive in woodland, the larvæ are not present when the crop is planted.

The larvæ attack the young corn near the surface of the ground and burrow into the base of the stalks, the outer portion of the stalk being frequently girdled. If the stalks are small when attacked, they are either killed or so stunted or dwarfed that they never fully outgrow the injury, and produce little or no grain. Much of the corn is attacked just after the seed has sprouted. The larvæ frequently burrow into the folded leaves as the corn is coming through the ground. As the leaves unfold they show transverse rows of holes. When the stalks reach a height of a foot or more comparatively little damage is done. Several larvæ are frequently found about the roots of a single stalk, and as many as 22 have been collected from a single hill of corn. In wet weather injury is not apt to be so severe, as the plants are then more vigorous and the weeds, which furnish suitable food for the worms, more plentiful. As with tobacco, corn is attacked when the natural food supply of the "worms" is cut off.

GENERAL FEEDING HABITS.

The feeding habits of the "wireworm" on plants other than corn and tobacco are, in a general way, the same. There is a tendency to girdle soft-rooted plants, such as plantain and the wild carrot (Pl. II, fig. *b*), and the larvæ are often found embedded in cavities where they have fed. The buckhorn plantain (*Plantago lanceolata*) is frequently killed where the infestation is heavy. A marked preference is shown for the natural food plants, and farmers, when the larvæ are especially troublesome, frequently take advantage of this fact by cultivating at first only one round to the row, allowing the weeds to grow in the center of the row until the corn or tobacco has become better established. In a plowed field the larvæ, if they have not finished feeding, concentrate about plantain, daisy, and stickweed (*Aster* spp.) which have not been killed by plowing.

The larvæ do not seem to travel far in search of food, as was ascertained by plowing badly infested land adjoining fields of corn and tobacco. When disturbed they crawl actively in either direction, and they will often spin a slender silken thread by which they may be suspended. They feed most actively at night.

THE PUPÆ.

The larvæ pupate in the soil near the plants on which they feed. Before pupation there often seems to be a rather long period during which the larvæ remain inactive in their cells. The pupal cells are usually found at a distance of from 1 inch to 6 inches from the base of the food plant and at a depth varying from one-half inch to 4 inches.

Table V shows the depths at which pupæ were found about various food plants in soils varying from hard stiff clays to loose sandy loams.

TABLE V.—*Depth at which pupation of the tobacco Crambus takes place, Appomattox, Va., 1910.*

Date.	Character of soil.	Food plant.	Depth.	Date.	Character of soil.	Food plant.	Depth.
1910.			*Inches.*	1910.			*Inches.*
July 9	Red clay	Tobacco	2.5	July 11	Red clay	Tobacco	1
Do	Sandy loam	do	3.5	Do	do	Corn	2.5
Do	do	Plantain	1	Do	Sandy loam	Daisy	.5
Do	Red clay	do	.5	Do	Red clay	Plantain	1
Do	Black loam	Daisy	4	Do	do	Daisy	1.5
July 11	Gray sandy loam	Tobacco	3.5				

Numerous measurements made at different times gave results very similar to those shown above. The average depth at which pupation takes place was found to be about 1.5 inches.

The cells averaged about 9.5 mm. in length and 4.5 mm. in width (inside measurements). The lower portion of the cell is usually somewhat larger than the upper portion, the pupa lying in the larger end of the cell in convenient position for its egress. The cells are extremely fragile and are easily broken when removed from the soil. They are constructed of fine particles of earth and grains of sand interwoven with a silky weblike material. The walls are thin and the interior surface quite smooth.

The pupal period, as shown in Table VI, lasts from 10 to 15 days.

TABLE VI.—*Pupal period of the tobacco Crambus, Appomattox, Va., 1911.*

Larvæ collected—	Pupated—	Moth emerged—	Number of days.	Larvæ collected—	Pupated—	Moth emerged—	Number of days.
1911.	1911.	1911.		1911.	1911.	1911.	
June 18	July 7–10	July 21	11–14	July 1	July 8	July 22	14
Do	July 10–11	do	10–11	July 12	Aug. 1–3	Aug. 15	12–15
June 20	July 7–9	July 22	15–17	Do	July 15	Aug. 1	15
Do	July 12	do	10	Do	July 28–31	Aug. 10	10–13
Do	July 15	July 26	11	Do	Aug. 1–2	Aug. 15	13–15
July 1	July 28–31	Aug. 10	10–13	Do	Aug. 1	Aug. 12	12

Table VII shows the duration of the period during which the insect is in the pupal cell before and after pupation.

TABLE VII.—*Duration of prepupal and pupal periods of the tobacco Crambus at Appomattox, Va., 1911.*

Number of record.	Larvæ ceased feeding—	Moth emerged—	Days.	Number of record.	Larvæ ceased feeding—	Moth emerged—	Days.
	1911.	1911.			1911.	1911.	
1	June 18	July 10	22	7	July 9	Aug. 1	23
2	do	July 15	27	8	July 11	July 24	13
3	do	July 16	28	9	July 13	July 29	16
4	July 3	July 18	15	10	July 14	Aug. 3	20
5	do	July 20	17	11	do	July 29	15
6	do	July 19	16				

NATURAL ENEMIES.

In spite of its long larval period the tobacco Crambus does not seem to be largely parasitized, at least during the later stages, this being due presumably to the subterranean habits of the larvæ and the protection afforded by the loose web in which they usually lie when not feeding. Nevertheless parasitic and predaceous enemies are doubtless factors in keeping the insect in check. The vast number of newly hatched larvæ as contrasted with the number found later in the season shows that comparatively few survive the earlier larval stages. This reduction is due in part to various natural enemies the exact or relative importance of which it is hard to estimate.

Various carabid beetles have been observed to feed on the larvæ. Among them were *Calosoma calidum* Fab. and *Chlænius tomentosus* Say. Adults and larvæ of Harpalus (*Harpalus pennsylvanicus* De G. and *H. faunus* Say) were observed to be very abundant about roots of oxeye daisy and plantain which were heavily infested with Crambus larvæ. As the species of Harpalus are known to be general feeders, they were thought to feed on the larvæ of the Crambus. The adults, when confined in tubes with larvæ, occasionally fed on them.

Spiders of several species were observed to feed on the larvæ, and large numbers of the moths are captured in spider webs in weedy fields.

Ants also occasionally attack the larvæ. An ant found carrying a partly grown larva at Chatham, Va., was examined by Mr. Theodore Pergande and found to be a species of Solenopsis.

W. G. Johnson, in Maryland, reported the rearing of an undetermined hymenopterous parasite from the larvæ. No parasitic Hymenoptera were secured from the rearing cages at Appomattox, although large numbers of larvæ were confined.

Several Diptera were observed in cages containing larvæ on various occasions, but actual proof of parasitism was not obtained, although a species of Phoridæ was secured from tubes containing larvæ under circumstances pointing strongly to parasitism.

In the National Museum are specimens of a hymenopterous parasite, *Perisemus prolongatus* Prov., labeled as reared from larvæ of *Crambus caliginosellus* from La Fayette, Ind. The record is doubtful, however, as the notes concerning the specimens in the files of the Bureau of Entomology clearly refer to a different species of Crambus as the host.

Birds are a factor in keeping the tobacco Crambus in check. Two species, the quail (*Colinus virginianus*) and the kingbird (*Tyrannus tyrannus*) were observed by the writer to capture the moths, and others are known to feed freely on moths of this genus. F. M. Webster states that the wood pewee (*Myiochanes virens*) was observed to

destroy large numbers of *Crambus laqueatellus* at Haw Patch, Ind., and C. H. Fernald observed barn swallows feeding on different species of Crambus in Maine. Meadowlarks frequent weedy fields which harbor the larvæ of Crambus, and as these birds are known to feed on various species of cutworms, they doubtless feed also on the larvæ of the tobacco Crambus.

REPRESSION.

CULTURAL METHODS OF CONTROL.

Injury from the tobacco Crambus occurs where crops susceptible to injury are grown on weedy land. Tobacco or corn planted on land which has been under clean cultivation the previous year and kept free from weeds which live throughout the winter does not suffer serious injury. *The larvæ can not live over winter in the soil from the previous summer unless plants on which they are able to feed are present.* All field experiments and observations so far have shown that the most effective means of control consist of freeing the land from the weeds, such as buckhorn plantain, daisy, stickweed, etc., which have been found to be the natural food plants of the larvæ.

There are many methods by which weeds may be eradicated or controlled, but the most practical and effective is the systematic rotation of crops. Sowing clean seed, preventing weeds from ripening seed, fall or winter plowing, the use of lime or of certain fertilizers, and doing away with wide fence rows are important preventive measures. Mowing and burning over weedy fields destroys many weed seeds and weeds which live over winter, and also destroys many injurious insects. Burning during August or September has been found to destroy the eggs and young larvæ of the tobacco Crambus, but as this method destroys humus, which is so badly needed in most tobacco soils, it is in most instances not advisable.

Many weeds are "soil indicators," their presence showing that the soil is lacking in fertility and in some instances pointing to a deficiency of lime.

CLEAN SEED.

One of the main factors in the control of weeds is clean seed, and the importance of procuring such seed can hardly be overestimated. Many weed pests are introduced and disseminated in the seed of various crops, such as grass and clover. As tobacco or corn must frequently be grown on land which has previously been in these crops, and as injury from the tobacco Crambus is apt to occur if the meadows have been weedy, it is desirable, for this and other reasons, to have the meadows as free from weeds as possible.[1] Owing to

[1] An analysis made by the Massachusetts Experiment Station shows that 1 ton of oxeye daisy (cured) withdraws from the soil approximately 25 pounds of potash, 8.7 pounds of phosphoric acid, 22 pounds of nitrogen, and 26 pounds of lime. To restore the stated amounts of the first three constituents to the soil it would be necessary to apply about 50 pounds of muriate of potash, 65 pounds of superphosphate, and 140 pounds of nitrate of soda. (Farmers' Bul. 103, U. S. Dept. Agr.)

careful cultivation of previous crops, the land is frequently fairly free from weeds when seeded to meadow; so that if the clover and grass seed has been sown pure there will be few weeds in the tobacco field or cornfield.

An examination of samples of clover and grass seed procured from farmers and seedsmen in various sections of Virginia shows that seeds of buckhorn plantain and oxeye daisy—both natural food plants of the tobacco Crambus—are common. Of 30 samples examined by the seed expert of the Virginia State department of agriculture during 1910, 28 contained seeds of oxeye daisy, and of these, 5 contained plantain and daisy. Of 70 samples of clover, redtop, and timothy seed examined at the Virginia Experiment Station in 1909, seeds of buckhorn plantain were found in 16.[1]

The United States Department of Agriculture and those in charge of similar work in many of the States have provided means by which samples of seed may be examined for purity by experts. Some of the States, also, have laws compelling dealers to furnish a stated guaranty as to the purity of the seeds sold.

WEEDS TO BE ELIMINATED.

The buckhorn plantain (*Plantago lanceolata*) is one of the numerous naturalized weed pests from Europe. It ranks among the worst weeds, particularly upon the lighter soils and on clay uplands. "Ray-bud," "rib-grass," "ribwort," "buck plantain," "English plantain," "ripple," "ripple grass," and "narrow plantain" are names applied to the plant in different sections. It is perennial or biennial and is common in meadows. The seeds are widely distributed with clover seed, from which it is difficult to separate them. Rotation of crops, thorough cultivation, and the use of clean farm seed are the usual methods for its control.

The oxeye daisy (*Chrysanthemum leucanthemum*) (Pl. II, fig. *a*) is also a naturalized species from Europe. It is often abundant on old or poor soil. It spreads from the seeds, which are distributed in various farm seeds, in hay, and in manure; also, by shoots from the perennial root stocks, which must be entirely killed before the plant can be wholly eradicated. It is best controlled by rotation of crops, by smothering out by means of cowpeas or other suitable soiling crops, and by thorough cultivation. It is a bad weed pest in meadowland. The seed can be prevented from ripening by mowing the hay early.

White top or fleabane (*Erigeron annuus* and other species) is a common pest in meadows. In some localities it has been found to be a food plant of the tobacco Crambus. Early mowing of infested meadows before the seeds ripen and pasturing with sheep, which

[1] Bul. 184, Va. Agr. Exp. Sta.

readily eat the weed, are control methods commonly practiced. Chemical sprays are fairly effective, but can not be used in meadows where clover is grown, as clovers are killed by the solution. Sprays have been found most effective while the plant is in bloom.

The stickweed or aster (*Aster ericoides*), known also as frostweed, steelweed, white heath, etc., and related species, are common and abundant weeds in old fields in tobacco-growing sections of the Atlantic States. They are perennial and thrive on poor soil. It is useless to try to eradicate them completely, but they can be readily controlled by growing cultivated crops and by putting the land in a higher state of fertility by the use of lime and clover. Aster is not a usual food plant of the tobacco Crambus, but as the weed is so frequently associated with daisy and plantain, which thrive best under similar soil conditions, its control is essential in the preparation of land for tobacco.

CROP ROTATION.

One of the main reasons for a rotation of crops is that the accumulation of weeds in meadowland and pastures may be destroyed during the cultivation of the crop that follows. A rotation found very satisfactory by the Virginia experiment station has been devised by Mr. E. H. Mathewson, Crop Technologist of the Bureau of Plant Industry. This plan is slightly modified to meet conditions in different tobacco-growing sections. It calls for a seven-year rotation of crops, as follows: *First year,* tobacco, fertilized heavily; *second year,* wheat without fertilizing; *third and fourth years,* mixed grasses and clover, seeded alone early in the fall and top dressed early in the spring with 200 to 300 pounds of nitrate of soda; *fifth year,* corn, with barnyard manure and a small amount of fertilizer; *sixth year,* cowpeas, fertilized with a little acid phosphate and sulphate of potash; *seventh year,* tobacco.

Crops such as cowpeas, soy beans, and crimson clover, which aid so greatly in fitting land for increased and more profitable yields of tobacco and corn, not only add humus to the soil and increase the fertility, but help to eradicate certain weeds by smothering them out. The weeds are also destroyed or prevented from maturing seed when crops are plowed under. Although eggs of the Crambus may have been deposited in such a field, the larvæ can not survive until the tobacco is planted unless there are weeds which remain alive over winter to supply them with food.

The following rotation experiments have been under observation during the present investigation:

A test with tobacco following crimson clover was conducted as a cooperative experiment on the J. R. Horsley farm in Appomattox County, Va., in the season of 1910–11. The field selected contained

4 acres. It was in corn during the season of 1910. Previous to plowing for corn the field was in weedy sod. The corn was badly injured by the Crambus and was replanted twice. At the last cultivation of corn in July, crimson clover was sown. Rains were frequent during the latter part of the summer, and a fairly good stand of clover was secured. There were some weeds, in spots, which cultivation at the time clover was sown had not destroyed. The field was planted to tobacco during the season of 1911. Damage by the Crambus was estimated to be about 6 per cent.

A test with tobacco following cowpeas was conducted as a cooperative experiment on the S. L. Ferguson farm, Appomattox County, Va., in the seasons of 1911 and 1912. A field containing about 6 acres was used in the experiment. The land previous to plowing for cowpeas was in weedy pasture, and numerous Crambus larvæ had been observed. A good growth of the cowpeas was secured. The land was deeply plowed during winter and was prepared for planting to tobacco during the third week in May, 1912. Scarcely any injury from the Crambus to the first planting was observed. After the first planting damage from the Crambus and from other causes was estimated to be less than 4 per cent. In the check field, where conditions were similar to those in the experimental field, except that a crop of cowpeas had not been grown, there was an estimated damage from the Crambus of about 9 per cent. The sod in the check had been winter-plowed.

In the plats of the Virginia Tobacco Experiment Station, at Appomattox, nine experiments were under observation, as detailed below.

The first experiment was with tobacco planted on sod in an old weedy pasture. A large part of the first planting was destroyed. The plat was replanted three times. About 9 per cent of a stand was secured by the second week in July. Owing to injury from "wireworms" and the large percentage of late plants the value of the crop was decreased 25 per cent as compared with plats in which an early stand of plants had been secured.

The second experiment was with tobacco following cowpeas on land that had been uncultivated for several years and was very weedy. Almost a perfect stand of plants was secured at the first planting, which was made the last week in May. The injury (decrease in the value of the crop) was less than 1 per cent.

The third experiment was on a plat used for fertilizer tests. The condition of the land was similar to that used in the second plat, except that cowpeas had not been grown during the preceding season. The tobacco was replanted three times. The decrease in the value of the crop was 7 per cent.

The fourth experiment was again with tobacco planted on sod. There were few weeds in the sod. Nearly a perfect stand of plants was secured at the first planting, which was made during the last week in May. The plat was replanted once. The loss was estimated at less than 1 per cent.

The fifth experiment was again with tobacco following cowpeas. A perfect stand of plants was secured at the first planting, made during the last week in May. Injury from the tobacco Crambus was estimated at less than 1 per cent.

The sixth experiment was with tobacco planted on red-clover sod. The stand of clover had been good and there were few weeds. Tobacco was planted during the last week in May. A good stand was secured at the first planting. Loss from the Crambus was estimated at less than 1 per cent.

The seventh experiment was on spring-plowed land where stickweed, daisy, and plantain had been abundant. The tobacco was planted during the second and third weeks in May. The loss was estimated to be about 20 per cent, owing to late plants, the tobacco having been replanted three times. Injury from the Crambus was worst in the portion of the field where weeds had been most abundant.

The eighth experiment was with tobacco following rye. The stand of rye had been poor and the stubble was weedy. The first planting was made on June 8, and was almost completely destroyed. Tobacco was replanted three times. A stand of 90 per cent was secured by the second week in July. The estimated decrease in the value of the crop was about 30 per cent.

The ninth experiment was with tobacco following cowpeas. The first planting was made on June 2. About 20 per cent of plants were injured by "wireworms." The plat was replanted once, there being only slight damage after the second planting. The estimated loss in value of the crop was about 10 per cent. Most of the injured plants were in the end of the plat where the stand of peas had been poor.

Three experiments were under observation at the Virginia Tobacco Experiment Station at Chatham in 1910 by Mr. R. P. Cocke, superintendent of the station.

In experiment No. 1 tobacco was preceded by corn in which crimson clover was sown at the last cultivation. This clover was fallowed May 2. The corn was kept clean of weeds and grass. Tobacco was set June 6. The first replanting was made June 14 with 5 per cent of the plants injured; the second replanting was made June 23, with 3 per cent injury; and the third replanting, June 28, with 2 per cent injury. About 97 per cent of a stand was finally secured after the third replanting.

In experiment No. 2 tobacco followed corn, in a plat used for fertilizer tests. Tobacco was set June 6. The first replanting was made June 14, with 5 per cent injury; the second replanting, June 23, with 3 per cent injury; and the third replanting, June 28, with 2 per cent injury. About 98 per cent of a stand was secured after the third replanting.

In experiment No. 3 tobacco was planted after a cover crop of wheat, in variety test plats. The wheat was fallowed May 1. Tobacco was set June 7. The first replanting was made June 17, with 20 per cent injury, and the second replanting, June 28, with 6 per cent injury. About 95 per cent of a stand was secured. In these plats it was estimated that about 5 per cent of the entire loss was due to cutworms and to true wireworms (larvæ of Elateridæ).

SUMMER PLOWING.

The moths are local in habits and do not fly far from the weedy fields, which furnish protection for them and which are suitable places for them in which to deposit eggs. On emerging from plowed or bare land, or from fields in which the vegetation is not suitable for protection or for egg deposition, they fly to surrounding fields where conditions are more favorable. The land from which emergence took place will then be left free from worms which, if present would attack the crop the following year.

The preparation of weedy land for tobacco or corn must, therefore, be commenced the season before the crop is planted. Best results have been obtained by summer plowing, as the land was thus rendered bare of vegetation, and conditions were not suitable for egg laying when the moths emerged. By this means infestation of the land is prevented in the first place. It has been found that it is difficult to prevent injury, or to eradicate the worms, if they have once become established. Summer treatment of land makes conditions unfavorable for the moths to deposit eggs, destroys weeds which furnish food for the young larvæ, and kills many of the insects while in the pupal stage.

The results of an experiment made in 1910 to ascertain the effect of plowing on pupæ is given in Table VIII. Larvæ were placed in large field cages. When the greater number had pupated, one of the cages was removed temporarily and the land plowed.

TABLE VIII.—*Effect of plowing on pupal stage of the tobacco Crambus.*

Cage No.	Number of larvæ.	Collected.	Moths emerged.	Number.	Per cent.
1	200	June: Second and third week	July: Third and fourth week	84	42
2 (check)	200	do	do	118	59

Pupation takes place at an average depth of 1½ inches. The pupal cells are fragile and easily broken up by plowing or disking. Many of the pupæ are deeply buried by plowing and the moths are unable to reach the surface.

The satisfactory results following summer treatment of land, whether or not cowpeas or other similar crops are grown, are mainly due to the fact that conditions are made unfavorable for the deposition of eggs by the moths and for the growth of newly hatched larvæ.

FALL AND WINTER TREATMENT OF LAND.

During September, 1909, two cultural experiments were begun in Appomattox, Va., to ascertain the effect of fall and winter treatment of land already infested with Crambus larvæ.

The field selected on the J. F. Purdum farm contained five plats of one-half acre each. In this experiment (experiment A) fall and winter preparation of the tobacco land gave decidedly beneficial results. The field had been in pasture previous to plowing, but the growth of weeds was not so rank as on the land used in experiment B. The following were the results obtained in each of the plats:

Plat No. 1.—Ground plowed during second week in December, 1909. Thoroughly disked during first week in January, 1910. Tobacco planted during last week in May. Number of plants, 2,200. Number replanted, 89. Per cent injured, 4+.

Plat No. 2.—Land plowed during first week in January, 1910. Disked during second week in February. Tobacco planted during last week in May. Number of plants, 2,350. Number of plants reset, 165. Per cent injured, 7+.

Plat No. 3.—Land plowed during last week in February, 1910. Disked during third week in March. Tobacco planted during last week in May. Number of plants, 2,280. Number of plants reset, 138. Per cent injured, 6+.

Plat No. 4.—Land plowed during third week in March, 1910. Disked during third week in April. Tobacco planted during last week in May. Number of plants, 2,214. Number of plants reset, 251. Per cent injured, 11+.

Plat No. 5 (check plat).—Land plowed during third week in April. Prepared for planting during last week in May. Tobacco planted during last week in May. Number of plants, 2,225. Number reset, 375. Per cent injured, 17+.

Tobacco in all plats was replanted twice. A good stand of plants (about 98 per cent) was secured by July 4. After July 4 there was but slight injury from the worms. The land had been heavily fertilized, and the tobacco made a fine growth.

The second tobacco cultural experiment was conducted on the farm of Mr. J. R. Horsley (experiment B), in Appomattox County, Va. Four plats, each containing 1 acre, were included in the experiment. Two check plats, one at each end of the experimental plats, were used. Each of these contained 1 acre. The growth of weeds was heavy, stickweed, daisy, and buckhorn plantain being abundant.

In this test beneficial results from fall and winter plowing were not so conclusive as in the experiment on the Purdum farm (experiment

A). On plat No. 1 the effect of mowing and burning the weeds after the eggs had hatched was noted.

Plat No. 1.—Weeds mowed and burned during third week in September, 1909. The land was not disturbed until the ground was prepared for planting, during the third week in May. Number of plants in plat, 4,400. Number of plants reset, 610. Per cent injured, 13.8+. Tobacco replanted twice.

Plat No. 2.—Ground plowed during last week in September, 1909. In March, April, and May it was disked and harrowed at frequent intervals, no vegetation being allowed to grow before the tobacco was planted, in order, if possible, to starve out the hibernating larvæ. Number of plants, 4,400. Number replanted, 415. Per cent injured, 9.4+.

Plat No. 3.—Land plowed during second week in March and not disturbed until just before planting. Number of plants, 4,400. Number of plants reset, 410. Per cent injured, 9.3+.

Plat No. 4.—Land plowed during third week in December, 1909. Nothing further done to it until prepared for planting during last week in May, 1910. Number of plants, 4,400. Number replanted, 540. Per cent injured, 12.2+.

The results of these experiments are shown also in Table IX.

All plats were replanted twice. A good stand of 98 per cent was secured by July 5.

TABLE IX.—*Effects of fall and winter treatment on injury by the tobacco Crambus in 1909 and 1910.*

Experiment No.	Preliminary treatment.	Time of treatment.	Later treatment.	Time.
A1	Plowed	Second week of December, 1909	Thoroughly disked.	First week of January, 1910.
A2	do	First week of January, 1910	Disked	Second week of February.
A3	do	Last week of February	do	Third week of March.
A4	do	Third week of March	do	Third week of April.
A5	do	Third week of April		
B1	Weeds mowed and burned.	Third week of September, 1909	Disked and harrowed at frequent intervals.	March, April, May.
B2	Plowed	Last week of September		
B3	do	Second week of March		
B4	do	Third week of December		
B5	do	First week of April	Disked	First week of May.

Experiment No.	Planted tobacco.	Number of plants.	Number reset.	Per cent injury.
A1	Last week of May	2,200	89	4
A2	do	2,350	165	7
A3	do	2,280	138	6
A4	do	2,214	251	11
A5	do	2,225	375	17
B1	Third week of May	4,400	610	13.8
B2	do	4,400	415	9.4
B3	do	4,400	410	9.3
B4	do	4,400	540	12.2
B5	do	8,800	1,218	13.9

In the season of 1910–11 another series of cultural experiments was conducted on the J. F. Purdum farm, in Appomattox County, Va The land previous to preparation for tobacco was in meadow

(timothy, herd's grass, and clover) which had been quite weedy. Natural food plants of the tobacco Crambus were abundant. This series was made for the purpose of ascertaining the effect on the tobacco Crambus of preparation of weedy land at different times during the fall and winter as compared with spring preparation of land. The field was divided into 6 plats containing one-half acre each. Tobacco was planted in all plats on the same date. The amount of fertilizer applied to each plat was the same.

In plat No. 1 the land was plowed September 6, 1910, and fallowed February 25, 1911. It was harrowed and disked on April 3, April 10, April 20, and May 3. The stand of tobacco was nearly perfect after the first planting except along one end of the plat. The percentage of a stand secured was 95.4. In the preparation of this plat it will be noticed that the land was plowed during the first part of September, a time just after the larvæ had hatched.

Plat No. 2 was plowed December 8, 1910, and fallowed February 28, 1911. It was harrowed and disked on April 3, April 10, April 20, and May 3. Tobacco was replanted once. About 85 per cent of a stand was secured at the first planting.

Plat No. 3 was plowed January 8, 1911, and fallowed or replowed February 28, 1911. It was harrowed and disked on April 3, 10, and 20 and May 3. Tobacco was replanted once. About 85 per cent of a stand was secured at the first planting.

In plat No. 4 the land was plowed on April 11. No further treatment was given until the third week in May, when the land was prepared and bedded for planting. The tobacco was replanted three times. About 51 per cent of a stand was secured at the first planting.

In plat No. 5 the land was plowed on January 18, 1911, and disked May 15. Tobacco was replanted three times. About 70 per cent of a stand was secured at the first planting.

Plat No. 6 served as a check plat. The land was plowed during the third week in April, and was prepared for planting on May 15. Tobacco was replanted three times. About 55 per cent of a stand was secured after the first planting.

Further cultural experiments were conducted on the S. L. Ferguson farm, in Appomattox County, Va., in the season of 1911–12. This series was made to ascertain the effect of deep winter plowing and subsoiling of pasture land infested by the Crambus. The field of which the experimental plats were a part had been in sod for a number of years and was used as pasture land. The general conditions for the experiment were ideal. The oxeye daisy, buckhorn plantain, and stickweed were abundant. There was not a rank growth of weeds, however, as the field had been quite closely pastured. The field was deeply plowed in February, a subsoil plow following the turning plow, and the clay subsoil was broken up to a depth of several

inches. The tobacco in all plats was planted at the same time. The kind and amount of fertilizer applied was the same in all plats, and after the first cultivation all plats received the same treatment. The land was divided into 3 plats of 2 acres each and 1 plat containing one-half acre. Below are given the details of each experiment and the results obtained.

Plat No. 1 contained 2 acres. It was deeply plowed and subsoiled in February, 1911. The land was thoroughly disked and harrowed at frequent intervals during March, April, and May and kept almost entirely free from weed growth until tobacco was planted. The stand of tobacco was practically perfect. Only an occasional plat could be found which showed damage from Crambus larvæ.

Plat No. 2 contained 2 acres. The land was deeply plowed and subsoiled in February, 1911, and was not disturbed until prepared for planting in May, when it was deeply disked, harrowed, and bedded just before planting. Ninety-four per cent of a stand was secured at the first planting. The plat was reset once.

Plat No. 3 contained one-half acre. The land was plowed and subsoiled in February, 1911, as in plats Nos. 1 and 2. The land was not disturbed until prepared for planting as in plat No. 2. Weeds and grass were allowed to grow after planting. The middle of the row was not disturbed until after the first cultivation, in order to provide natural food for the Crambus larvæ, so that they would not be forced to attack the tobacco plants. The infestation of this plat was not heavy enough, so that the effect of this treatment, which is said to be practicable under certain conditions, could be accurately determined. The stand of tobacco secured at the first planting was 96 per cent. A few larvæ were found in the weeds left in the middle of the row.

Plat No. 4 was used as a check. The land was plowed and prepared for planting just before the tobacco was set out. The weed growth and general conditions were similar to those in plats Nos. 1, 2, and 3. The stand secured at first planting was 86 per cent. The tobacco was replanted twice. In land adjoining this tract which had been under clean cultivation during the previous summer and where there was no weed growth, about 98 per cent of a stand of tobacco was secured at the first planting. This land had been prepared for planting in practically the same manner as in the check plat, No. 4.

CHEMICAL SPRAYS FOR WEED DESTRUCTION.

Certain chemical sprays, such as iron-sulphate (copperas) solution, copper-sulphate (bluestone) solution, and common-salt solution, are frequently used for eradicating weeds and under certain conditions have been found very effective. The success of this method of eradicating such weeds as oxeye daisy and wild mustard from grain and pasture fields without injury to the grains or grasses depends largely

on the fact that cereals and grasses are narrow-leaved plants with a single seed leaf, whereas the weeds injured are broad-leaved plants with two seed leaves. Spraying with a solution of iron sulphate at a strength of 1 pound to one-half gallon of water was found to be fairly effective on the oxeye daisy in a test made at Appomattox, Va. While spraying may be practical where certain weeds in grain fields are to be eradicated, it is hardly a suitable remedy under most conditions in tobacco-growing sections, except possibly where small patches of weeds are to be destroyed. Chemical sprays have been found to be more effective when applied on warm bright days when the plants are dry. Immediately after weeds have been cut off close to the ground an application of salt, kerosene, crude oil, or acid solutions will often be found effective. In eradicating weeds from pastures the salt solution is preferable, as copper-sulphate solution is poisonous to stock.

LIMING.

Aside from improving the mechanical and chemical condition of many soils, liming will be found to aid greatly in the control of several of the weed pests which have been found to be the natural or favorite food plants of the tobacco Crambus. Control of weed pests may be accomplished by making soil conditions less favorable for the weeds, or by making conditions more favorable to the cultivated crop. Many weed pests, like other plants, require for their best development certain soil conditions; and they are excessively abundant in certain localities because soil conditions are peculiarly favorable to their growth, or because conditions are less suited to more desirable plants which under favorable soil conditions would crowd them out. A change in the condition of the soil, brought about by the use of lime, will often bring about a marked effect in checking or preventing the growth of a weed pest, and at the same time make the soil better adapted to the growth of certain cultivated crops such as clover.

The sheep sorrel[1] (*Rumex acetosella*), on which newly hatched Crambus larvæ frequently feed, thrives in acid soil. Where lime had been applied to certain fields, and to some of the State experiment station plats in Appomattox County, Va., the sheep sorrel was practically eradicated or at least checked by the better growth of the clover. Plantain, daisy, and aster (stickweed), all food plants of the worms, are weeds which flourish in acid or worn-out soils. In all cases where data have been secured, the use of lime has resulted in a marked decrease in the abundance of these weeds. Most soils in the Piedmont region of the Eastern States are greatly benefited by lime, and its use has in many instances resulted in markedly increased yields of tobacco. In plats of alfalfa at the Appomattox experiment station

[1] Attempts to rear larvæ in cages containing only sheep sorrel were not successful.

there was scarcely any plantain (*Plantago lanceolata*) after a heavy application of lime had been made, and there was an excellent crop of alfalfa. In the unlimed check plats plantain nearly covered the ground, and there was a very poor growth of alfalfa.

Increased fertility of the soil may also aid in the extermination of a weed, as was noticed where heavy applications of acid phosphate had been made to meadow land on which there was a heavy growth of the oxeye daisy. The year following the application of the acid phosphate but few plants of the daisy could be seen. In this manner certain weeds may often be crowded out by grasses or clovers which are enabled to make better growth owing to greater fertility.

The experience of the best tobacco growers has shown that intensive culture gives largest profits, and no expense or trouble should be spared in putting the ground in the best possible condition in every respect before the crop is planted. By commencing the preparation of weedy land the year before it comes in corn or tobacco, an excellent opportunity is afforded to apply lime. Such land can often be conveniently plowed in winter and during spring or early summer, and easily be put in condition for such crops as crimson clover, cowpeas, etc., which may be profitably followed by tobacco or corn the succeeding year.

FERTILIZERS.

From observations of tobacco fields during the seasons of 1910 and 1911 it is evident that where the land receives heavy applications of nitrogenous fertilizers the damage from the worms is not so great as where light applications are made. Just as many plants are attacked by the worms, but vigorous and rapidly growing plants are more apt to recover from injury. This was very noticeable in the fertilizer test plats of the Virginia experiment station at Appomattox in 1910.

INSECTICIDES AND REPELLENTS.

The following insecticides and repellents were tested: Arsenate of lead, Paris green, tobacco extract, nicotine sulphate, tobacco dust, kerosene, kainit, and calcium cyanamid. In no instance were results secured which would indicate that the substances tested were of much practical value in combating the tobacco Crambus. The following field notes give details of some of the experiments:

ARSENATE OF LEAD.

In experiment A, with powdered arsenate of lead, 1½ ounces of the poison to 2½ gallons of water was used. Two hundred plants were treated, the entire plant being dipped into the solution. The plants were set in land which had been prepared a few days before. The field had been weedy and the worms were numerous. Two hundred untreated plants were kept as a check. On examining the plants five days later 22 injured plants were found in the poisoned plat and 36 injured plants in the

check plat. Three live larvæ which had tunnelled in the stalks and were apparently uninjured were found in plants in the poisoned plat. All treated plants had lived, but were not as vigorous in appearance as those not treated.

In experiment B, with arsenate of lead paste, the poison was used at the rate of 2 ounces to 2½ gallons of water. The tops only were dipped. One hundred plants were treated and 100 left untreated. The plants were examined five days after transplanting. There had apparently been some injury from the poison, as the plants were in best condition in the untreated plat, while those treated were somewhat stunted or dwarfed. Eight injured plants were found in the poisoned plat. Five plants were found injured in the untreated plat.

PARIS GREEN.

Paris green at the rate of one-fourth ounce to 3 gallons of water was used on 100 tobacco plants, and an adjoining row kept as a check. The entire plant was dipped in each case, and the plants set out at once. The field was weedy. It had been recently plowed and Crambus larvæ were numerous. A light rain fell a few hours after the plants were set. After eight days the plants were examined. Twenty-one plants were injured by worms in the poisoned row and 26 in the unpoisoned row. There had been some injury to the plants dipped in the poison solution, as the unpoisoned plants had a more vigorous start. In some instances plants in the poisoned row were only slightly eaten, thus indicating that the poison had acted as a repellent or had poisoned the worm before the plant had been badly eaten.

TOBACCO EXTRACT.

One row of tobacco plants in a field was sprayed with a 500-to-1 solution of tobacco extract, 320 plants in all being treated. The solution was applied with a compressed-air bucket sprayer. The substance did not prove effective in preventing injury. On June 6, five days after the mixture was applied, the plants were examined. Fourteen plants were found injured by worms in the sprayed row and 11 injured plants were found in the unsprayed row adjoining.

NICOTINE SULPHATE.

A 1,000-to-1 solution of nicotine sulphate was sprayed on 300 plants as in the foregoing experiment, and an adjoining row used as a check. The plants were examined four days after spraying. Eight plants had been attacked by worms in the sprayed row and 13 plants in the check row. While the foregoing substances did not prove of much value in preventing injury from the worms, they seemed to repel flea-beetles, as very few could be found on the treated plants whereas they were comparatively abundant on the unsprayed plants.

TOBACCO DUST.

Tobacco dust was scattered about tobacco plants directly after planting. One row containing 300 plants was used for the test and an adjoining row with the same number as a check. Eighteen plants were found injured by worms in the treated row. Few plants were found that were injured below the surface of the ground, the worm having entered the plant at the "bud" or terminal leaf in most cases. Sixteen injured plants were found in the row where the dust had not been applied. More of these plants had been injured below the surface of the soil than where dust had been applied, this indicating that the dust may possibly have some value as a repellent.

KEROSENE.

In the first experiment with kerosene the plants were dipped in a weak solution of kerosene emulsion and were set out on June 15. Only 30 plants were used in the test. None of these, when examined five days later, was found infested. There was apparently no injury to the plants from the kerosene. Two infested plants were

found in the check row of 30 plants. The number of plants treated was not large enough to make this test of much value.

In the second experiment kerosene was mixed with sand and a small amount sprinkled around 100 tobacco plants. One hundred plants in an adjoining row were used as a check. A light rain fell a few hours after the sand was applied. On June 18, eight days after treatment, the plants were examined. Sixteen were found injured in the treated row and 22 in the untreated row.

KAINIT.

In one experiment kainit was mixed with the soil in the hill before planting. Too large a quantity of the kainit was used in the test, as a considerable number of plants failed to grow. One hundred tobacco plants were put out in soil mixed with the kainit, and 100 plants in an adjoining row were left for a check. A number of infested plants were found where the kainit had been used, the substance evidently not being of much value as a preventive, as the worms often enter the plant at the "bud" or whorl of terminal leaves.

TURPENTINE.

In certain sections of Tennessee and Kentucky turpentine is said to have been used as a repellent for Crambus larvæ and cutworms. Before planting, the roots of the tobacco plants are dipped in water in which a small quantity of turpentine has been stirred.

A test on 1 acre of tobacco was made by Mr. Charles Armistead, of Clarksville, Tenn., and the field kept under observation by the writer. Entirely negative results were obtained. The following are details of the experiment: The tobacco was on weedy land containing an abundance of white top (*Erigeron annuus*) and plantain. The first planting was entirely destroyed. When the tobacco was replanted turpentine was used at the rate of 1 teaspoonful to 1 gallon of water, the roots of the plants being dipped in the mixture. On June 27, two weeks after planting, the tobacco was examined. Worms were still very numerous. Over 80 per cent of the plants had been entirely destroyed, in both treated and check plats. There seemed no apparent difference in infestation and damage between the treated tobacco and that on which no turpentine had been applied.

CALCIUM CYANAMID.

Calcium cyanamid (lime nitrogen) is said to have a repellent or poisonous effect upon insects, and on the suggestion of Mr. E. H. Mathewson, Crop Technologist of the Bureau of Plant Industry, Mr. B. G. Anderson, superintendent of the Tobacco Experiment Station at Appomattox, Va., and the writer made a test of the material during 1911, using the calcium cyanamid at the rate of 300 pounds per acre. The land selected had not been cultivated for several years. There was a rank growth of buckhorn plantain, oxeye daisy, and stickweed, and Crambus larvæ were exceedingly numerous, making conditions ideal for the test. The plat, containing one-twentieth of an acre, was divided into series of two rows each. The calcium cyanamid was used on two rows and the next two rows were kept as a check. On the treated rows commercial fertilizer at the following rate per acre was used:

	Pounds.
Calcium cyanamid	300
Acid phosphate	600
Sulphate of potash	100

On the check rows the fertilizer used (rate per acre) was as follows:

	Pounds.
16 per cent blood	300
Acid phosphate	600
Sulphate of potash	100

The calcium cyanamid analyzed about 17 per cent ammonia, this making the amount of plant food in the treated and check rows practically the same. The fertilizer was applied 14 days before the plants were set, as calcium cyanamid has the effect of stunting tobacco plants if applied directly before planting. It was applied to the rows with a drill, and thoroughly mixed with the soil by running a cultivator over the rows. The plants were set on June 8. By June 30 the plants in both treated and check rows had been almost completely destroyed by the Crambus larvæ, there being no indications of any beneficial effect from the calcium cyanamid in preventing injury. The tobacco was not replanted.

LEAD ARSENATE AND PARIS GREEN USED WITH COAL TAR ON SEED CORN TO PREVENT INJURY BY CRAMBUS LARVÆ.

Experiments in the use of arsenate of lead and Paris green with coal tar on seed corn to prevent injury by Crambus larvæ were conducted in 1910 on the J. F. Purdum farm.

In experiment A, arsenate of lead in paste form was used at the rate of 1 ounce to 1 gallon of water. One peck of shelled seed corn was allowed to soak in the solution about 10 minutes and dried by mixing with fertilizer (acid phosphate). A very little coal tar (about a tablespoonful) was then poured on the corn, which was thoroughly stirred until a thin coating of the tar covered each kernel. Fertilizer was then used to dry the tar. With an ordinary planter one-half acre was planted in seed prepared as just described. Fully one-third of the corn failed to germinate, possibly owing to exclusion of moisture from the seed by the tar, as the weather was dry. No benefit in preventing injury by the worms seemed to result. In the check plat the stand of corn was practically perfect. On June 16, four weeks after planting, a count was made in the treated and check plats of hills of corn showing Crambus injury. Eleven per cent of the hills showed injury in the treated plat and 13 per cent in the check plat.

In experiment B, 1 ounce of Paris green was used to 1 peck of shelled seed corn. A small amount of tar (about one tablespoonful) was poured over the corn, which was thoroughly stirred until a thin coating of tar covered each kernel. The corn was then dried by mixing with fertilizer to which Paris green had been added. One-half acre was planted with seed prepared in this manner. About one-fifth of the seed failed to grow. In the check plat the stand was practically perfect.

A count of hills of corn showing Crambus injury, made on June 16, four weeks after planting, showed the results of the treatment to be as follows: Injury in treated plat, 11 per cent; injury in check plat, 9.5 per cent.

SUMMARY OF ECONOMIC CONTROL.

(1) The eggs of the tobacco Crambus are deposited in weedy fields during July and August. They hatch in a few days. The larvæ remain over winter in the soil and complete their growth during June and July. They are in their most active feeding stage at the time tobacco or corn is planted.

(2) Injury to tobacco or corn occurs when these crops are planted on land which was weedy during the previous year. Crops planted on land which has been under clean cultivation are immune from injury.

(3) The weeds which have been found to be the more common natural food plants of the worms are the buckhorn plantain, oxeye daisy, stickweed, and whitetop. The presence of these weeds in meadows accounts for injury to tobacco or corn when planted on sod.

(4) The worms when once established in land where their natural food plants are abundant have been found difficult to control.

(5) Various insecticides and repellents have been tested, but without satisfactory results.

(6) Fall or winter plowing has been found to reduce injury, but is only partially effective, as some of the weeds remain alive and furnish food for the larvæ until the tobacco or corn is planted.

(7) Damage is best prevented by crop rotations, or by cultural methods that prevent growth of the weeds which are food plants of the worms, thus making conditions unfavorable for egg deposition by the moths *the summer before tobacco or corn is planted.* Summer plowing, thorough preparation of weedy land, and the growing of crops of cowpeas or crimson clover, preferably cowpeas, the year before crops subject to injury are planted, have been found to be the most satisfactory and practical means of control.

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